Calculating Simulation-Based Training Value: Cost Avoidance and Proficiency

Dr. Tim Cooley
DynamX Consulting
Castle Rock, CO
TCooley@DynamX.org

Mr. Greg Seavers
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

Dr. Steven Gordon
Georgia Tech Research Institute
Orlando, FL
Steve.Gordon@gtri.gatech.edu

Mr John Roth
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

Mr. Jose Rodriguez
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

ABSTRACT

For over a decade, leaders in the Department of Defense (DoD) have asked "What is the value of simulation based training?" or "Why should I spend one more dollar on simulation?". The easiest answer may be the qualitative benefits of simulation that pertain to areas like safety, availability, flexibility in scenarios, and protection of operational plans. But leaders want quantitative measures such as Return on Investment (ROI), and ROI for simulation has two major facets: cost and benefit (often called results). The authors' research has focused on answering the DoD questions with cost avoidance computations because cost avoidance is a key component of ROI calculations, and with proficiency improvement evaluations to determine if use of simulation has a quantitative benefit. The authors will present their methods of calculating cost avoidance over the last four years for many simulation-based training systems managed by the United States Marine Corps Program Manager for Training Systems (PM-TRASYS). The research has shown cost avoidance of over $2B across the PM-TRASYS systems analyzed, but the authors are also developing methods to refine these measures of cost avoidance. These more realistic measures are linked to live training requirements allowed to be conducted in simulation and/or to proficiency increases due to use of simulation. These same cost avoidance methods are now being applied to large scale exercises to show the value of using a mix of live-virtual-constructive systems in these scenarios. This paper will also discuss the management data that is gathered and depicted as part of the cost avoidance studies. This data captures use statistics by system and site, and includes data such as the number of Marines trained and munitions used. As will be shown in the paper, this study provides quantitative measures of simulation cost avoidance and results.

ABOUT THE AUTHORS

Tim Cooley, PhD is President and Founder of DynamX Consulting, a veteran owned consulting firm located in Castle Rock, Colorado. Dr. Cooley spent 16 years on the United States Air Force Academy faculty, both in uniform and as a civilian, holding numerous positions including DMSO Modeling and Simulation Chair, Deputy Department Head, and Senior Researcher. He has completed a number of innovative mathematical and cost analyses for the USMC, USAF, and OSD, and performed counter-terrorism research for Joint Staff.

Greg Seavers, MBA is Senior Operations Research Analyst with the U.S. Marine Corps Systems Command Program Manager for Training Systems in Orlando, FL. He is the Functional Lead for Cost Analysis for all PM TRASYS programs as well as the Tier 1 Cost Analyst for Product Manager Range Training Systems. A 26 year DoD cost analyst he is a Certified Cost Estimator/Analyst through the International Cost Estimating and Analysis Association.

Steve Gordon, PhD is the Orlando Field Office Manager for Georgia Tech Research Institute and the Director of Georgia Tech's Test and Evaluation Research and Education Center. He served 26 years in uniform in the United States Air Force and 5 more years as a federal government civilian employee as Technical Director for the Air Force Agency for Modeling and Simulation.

John Roth is an Operations Research Analyst with PM Training Systems Orlando. He is the Tier 1 Cost Analyst for all Collective programs at PM TRASYS. His experience includes Business Case Analyses (BCAs), numerous IGCEs, several Program Life Cycle Cost Estimates (PLCCEs) and multiple Source Selections. Prior to becoming a cost analyst, he spent over 7 years as a Naval Officer and has qualified in Surface Warfare and Nuclear Propulsion.

José Rodriguez-Sanjurjo is an Operations Research Analyst with the U.S. Marine Corps Systems Command Program Manager for Training Systems in Orlando, FL. He is the Tier 1 Cost Analyst for Product Manager Individual Training Systems. He has extensive research experience and has worked on research projects with the London School of Economics and Political Science, and Harvard University.

Calculating Simulation-Based Training Value: Cost Avoidance and Proficiency

Dr. Tim Cooley
DynamX Consulting
Castle Rock, CO
TCooley@DynamX.org

Mr. Greg Seavers
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

Dr. Steven Gordon
Georgia Tech Research Institute
Orlando, FL
Steve.Gordon@gtri.gatech.edu

Mr John Roth
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

Mr. Jose Rodriguez
USMC/PM-TRASYS
Orlando, FL
PMTRASYS@USMC.Mil

BACKGROUND

In September 2011, the United States Marine Corps Program Manager for Training Systems (USMC/PM TRASYS) engaged a team of PM-TRASYS Cost Analysts, Georgia Tech Research Institute (GTRI), and DynamX Consulting in a study to develop a methodology that would identify, quantify, and analyze the costs avoided by training with simulator systems versus performing the same training live. The objective of the study is to show the value (in terms of net cost avoidance and usage statistics) of training with simulation by calculating the net costs avoided by not firing "live" weapons, not flying "live" missions, not dropping "live" ordnance, or not driving "live" vehicles. Since the inception of the Cost Avoidance Study, some training systems have been modified to automate portions of the data gathering, and more reliable data gathering methods have been implemented. The available data from all tasked training simulators has been updated and analyzed by month and fiscal year and by all reporting sites through the early months of FY15. A complementary Proficiency Evaluation process has also been started with Proof of Concept completed on the impact of simulation-based training on proficiency of M1A1 tank crews undergoing training in the Advanced Gunnery Training System (AGTS) (Dunne, Cooley, and Gordon, 2014).

The two major facets of Return on Investment (ROI) studies on simulation and training are cost and benefit (benefit is sometimes called results) (Oswalt, et al, 2011). Historically, in order to account for the benefits of modeling and simulation (M&S), qualitative metrics were assessed, and the task was limited to collecting measures of these qualitative metrics and gathering a limited collection and analysis of quantitative use data (Murphy, Farr, and Loviscky, 2008). These studies are frequently time consuming and potentially complicated; it is sometimes difficult to ensure the metrics developed are measurable and complete. For example, for simulation-based training, qualitative statements like the ones listed below are true:

- "Simulation allows us to go where we cannot otherwise go,"
- "Simulation allows training in scenarios with any environmental conditions in spite of training site weather,"
- "Simulation allows mistakes and retraining without the risk level of live training."

These statements are true, but they do not have the evidentiary value of quantitative measures.

Complete ROI studies for training systems can require a high standard of documented training and readiness (T&R) allocations between live and simulator/simulation training. Unfortunately, few T&R allocations to simulation-based training exist at this time, because proficiency evaluation studies on those systems have not been conducted, and allocations of training simulation use to improve training effectiveness or unit readiness have not been determined.

Therefore, comparison of use costs may currently be the best alternative to a complete ROI study. Cost avoidance can be calculated by subtracting the actual use costs of the M&S system from the costs avoided if the same tasks would have been performed without M&S (in a live environment) over a predetermined time period. This metric can demonstrate and validate the worth of the M&S system without accounting for all the benefits, including improved training effectiveness and unit readiness, for instance. Before and during the Cold War era, especially before simulation became widely available and useful, training was conducted live by using large force deployments representing friendly and hostile forces and live-fire exercises; these deployments resulted in significant wear and tear

on weapon systems, negative impacts on the environment, and huge investments in transport, personnel tempo, and reset. Therefore, calculation of costs avoided by using simulators vice live assets is a realistic calculation.

In assessing the applicability of cost avoidance, there are several points to consider. First, data must be readily available to calculate the costs avoided due to using the M&S system. Therefore, data on weapons systems used, munitions delivered, forces deployed, and ammunition expended in the simulation should be tracked. In order to calculate the net cost avoidance, the operation and maintenance cost of the simulators must also be known. Hence, data must be available to calculate the actual costs, or at least the most significant costs, expended in operating the M&S system. In order to substantiate the worth of an M&S system, both the costs expended for use of the simulator and the costs avoided (by not using live weapons and systems) must be taken into account. Clearly, for cost avoidance alone to validate the worth of an M&S system, the costs avoided must be larger than the cost to operate the training system, as measured in terms of dollars.

This paper reports on the results of the cost avoidance study of the PM TRASYS training portfolio. It will discuss the rationale for costs not included and present the total cost avoidance across the portfolio and by system. Cost avoidance will change year to year for many reasons: change in the cost of live ammunition, cost of flying live aircraft, and the cost of driving live vehicles; change in the usage of the training system; and more accurate collected data due to automated collection, or increased vigilance of simulator system operators.

METHODOLOGY

Much groundwork had been laid in attempting to assess the value of simulation based training (Dunn, Cobb, and Dickenson, 1999; Mahon, 1999; Gordon, 2000; Oswalt, 2005; Gauvin, 2006) over the past two decades. However, there did not exist a well-defined framework to calculate cost avoidance. Many who had attempted to develop such a process, created a method that was theoretically robust and complete, but in practice was too detailed and cumbersome. Therefore, this process was desired to be accurate, but relatively simple and not time nor manpower intensive.

Guiding Principles

At the beginning, some guiding principles were established in order to bound the problem.

1. The initial procurement cost of a live system or a simulated system would not be included in the analysis. Only the annual operating and maintenance (use) costs of the simulator systems would be compared to the use costs of the weapons systems. This stipulation allows the comparison of simulator use costs to live system use costs. Hardware and software upgrades or refresh of simulator systems would be taken into account, where that data is known and reported, as these actions are maintenance actions and not part of the original procurement. Since the cost of a simulator training system is typically less than the cost of live weapons systems, this approach is more advantageous to live systems and calculates a lower cost avoidance for simulation-based training.
2. In general, personnel costs of the trainees and trainers (to include TDY costs) would not be included in the analysis because both live and simulation-based training require trainers and trainees. The sizes of the training audiences and the training team may be larger for live events due to the supporting forces necessary to sustain combat forces, but the calculation of those differences could be more appropriate in follow-on phases of the study, if at all. As an exception to this guiding principle, for contractor-operated simulation systems, the cost of the some of the contractor trainers is included in the contractor logistic support (CLS) amounts. Separating the trainer costs from the other CLS costs is difficult, thus those contractor trainer costs are included in the analyses. This assumption lowers the overall cost avoidance of using simulation-based training and is, again, more advantageous to live systems.
3. For simulators designed to train emergency procedures, only usage data would be collected. Systems such as the Family of Egress Trainers are developed to train Marines in avoiding deadly accidents, preventing injury, and saving lives. Reports clearly indicate that these systems accomplish these tasks and performing the emergency procedures live would require too much risk to life and limb. For that reason, the best option is to perform the training via simulator in a controlled environment, and the costs avoided are not a factor in the decision to support the simulator system.

With the guiding principles developed, a full list of desired data was developed to include the difficulty of obtaining that data.

Data Gathering

As the list of desired data was developed and examined it became apparent that the data desired was divided into four categories. The first is the usage data: number of Marines trained, hours trained, and simulator availability. For most systems this data was readily available. The second category is the training data which contains the simulated rounds fired by type, vehicle miles driven by type, aircraft hours (or sorties) flown by type, ordnance dropped by type, etc. This data was available but in some cases required some effort to extract from various reports. The third type of data was the cost for each of the ammunitions, ordnances, aircraft hours, vehicle miles driven, etc. so that the cost avoidance could be calculated. Some of this data was easily obtainable, other required information from USAF, OSD, or internet searches. Finally, there was data on the costs of operating and maintaining the simulator and the associated live training facilities that would be used if the training were conducted live. The Contract Logistics Support (CLS) costs were easily obtained. However, fixed costs of operating and maintaining the structure that housed the simulators, the data lines connecting simulators, security for the structure housing the simulator, electricity to run the simulator, etc. were not known and determined extremely difficult to obtain. Similarly, the operation and maintenance costs associated with live training infrastructure such as ranges, roads, and mounts, was also shown to be extremely difficult to calculate for individual elements. A list of desired data by category is listed below in Table 1. Obviously not every data type listed applies to every system. For example, a marksmanship trainer would not have vehicle miles driven or aircraft hours flown. There are only three columns as the cost was required for each type of training data desired.

Table 1. Desired Data to Calculate Cost Avoidance

Usage Data	Training Data	Infrastructure Data
Number of Marines Trained by Training System	Number of simulated ammunition rounds fired by type	Amount of Electricity used by the Simulator
Number Hours Trained by Training System	Number of simulated vehicle miles driven by type	Number of Man-hours required for security of the structure housing the simulator
Percent Availability by Training System	Number of simulated aircraft sorties/hours flown by type	Number of Man-hours required for maintenance of the structure housing the simulator
Number of Hours Operated by Training System	Number of simulated aircraft ordnance deployed by type	Contract, Logistics, and Support Costs, to include maintenance and refresh, by system
	Number of simulated Marines utilized for Battle Staff exercises	Cost to operate and maintain live ranges by type
		Cost to maintain roads
		Maintenance cost for weapons, vehicles, and aircraft[1]

Calculations and Significant Data Analysis

After listing all the desired data it was decided to calculate the cost avoidance using the available data and then integrate other data if and when it became available. Therefore, the data available at that time was: Number of Marines trained by system, Number of Hours trained by system, Number of simulated rounds fired by type, Number of simulated vehicle miles driven by type, Number of simulated aircraft hours operated by type, Number of simulated ordnance deployed by type, and the CLS cost by system. The data was available by system and broken down by site for each system (i.e. System A data was available, and broken out by the sites where system A was deployed). Cost data for each round, vehicle, aircraft, and ordnance was researched and acceptable values were obtained. In cases

[1] In many cases the maintenance cost for vehicles and aircraft are included in the cost per mile for vehicles and the hourly rate for flying aircraft.

where the cost data was for previous years, the DoD inflation rates were applied and the costs adjusted up to current year values.

Given the data available, the governing equation for calculation cost avoidance used was:

$$CA_{net} = \sum (\text{Number of Simulated Rounds Fired})*(\text{Cost per Round}) + \sum (\text{Number of Simulated Vehicle Miles Driven})*(\text{Cost per Vehicle Mile}) + \sum (\text{Number of Simulated Aircraft Hours flown})*(\text{Cost per Aircraft Hour}) - \sum (\text{Costs to Operate and Maintain the Simulator System}) \quad (1)$$

Cost Avoidance Methodology for USMC Training Systems

- **Overall Principle**: Net costs avoided are costs avoided by not performing training live minus cost to operate and maintain simulator/training system. Cost avoidance is reported by responding site and system. Management metrics are reported as Marines trained, hours used, and percent availability

- **Costs avoided** are only those costs that would be expended if the training was performed live
  -- Ammunition costs are calculate by taking the number of rounds fired multiplied by the cost of round
  -- Vehicle costs are ideally the number of miles driven multiplied by the cost per mile to drive vehicle (this is the most accurate calculation); when cost per mile is not available, we use the number of miles driven multiplied by the cost of fuel per gallon divided by miles per gallon expected for that vehicle (in this alternative calculation, other vehicle costs for maintenance and support are not included)
  -- Aircraft sortie costs are calculated by taking number of sorties multiplied by the length of the sortie multiplied by the cost per hour to fly the specific type of aircraft

- **Simulator costs expended** are Contractor Logistic Support (CLS) costs only
  -- Costs of acquisition of trainers/simulators are not included in the calculations because the calculations concentrate on use costs avoided, not acquisition costs of weapons or training systems
  -- TDY costs for Marines to travel to training simulators (and TDY costs for live training) are not calculated in this phase of the study
  -- CLS costs include standard operations and maintenance costs in addition to program management/overhead costs, cost of spares, and CLS workforce travel costs

- **Total costs avoided** on training systems are calculated based on best data available
  -- Some systems have incomplete usage data, and as a result, the true cost avoidance is higher
  -- Some live training costs such as range support costs, lead remediation, differences in TDY costs, and naval fire support costs are not included in this phase of the calculations; avoidance of these costs would increase the cost avoidance findings
  -- Simulator costs such as electricity, infrastructure operation and maintenance, and security are not included for most systems; the expenses are estimated to be insignificant, but would reduce cost avoidance

- **Training system benefits** are not considered in this phase of the project. Follow-on phases would consider that training decreases the risk of future accidents, simulation avoids damage to vehicles or injuries to personnel in live training, training can simulate a wide variety of weather and terrain conditions, simulation avoids the cost of live range clean-up, training systems placed convenient to USMC locations reduce travel of large groups of trainees and supporting forces, and similar benefits

- **Cost Data Sources**
  -- Ammunition costs from Standard Unit Price list provided by MCSC/PMAMMO
  -- Vehicle use costs/mile, miles per gallon, and fuel costs from VAMOSC and OSMIS data
  -- Air Force ordnance and hourly flight cost from AFI 65-503, Tables A11-1 and A15-1

Figure 1. Cost Avoidance Methodology

The data was entered into custom designed Microsoft Excel spreadsheets and the cost avoidance calculated for the systems of interest. Using the available data, at this point all systems had positive cost avoidance with most having a net cost avoidance > $10M. A few systems had net cost avoidance of $100M and up. At this point, an analysis needed to be completed as to the impact of not including the data that was difficult to obtain. The question was, "Is the data not considered significant to the overall net cost avoidance results?" The first data we considered in the analysis was live range clean-up costs (i.e. lead remediation). A quick investigation showed that these costs are on the order of $75,000 - $100,000, each year across the Marine Corps. Apportioning the cost fairly across the many types of training that use the ranges would be difficult. However, even if the total range clean-up cost were *added* to the net cost avoidance of the single system with the lowest net cost avoidance that would use firing ranges, it represents an increase in the net cost avoidance of 0.13%. Of the costs that would *decrease* net cost avoidance, electricity data was obtained for one system. This training system uses 1.56KwH of electricity. Its average usage is 65,300 hours/year and it has an average annual net cost avoidance of $621M. Across the United States the average electricity cost is $0.102/KwH. Therefore, the total annual cost of electricity for this system is $10,391 or .002% of the net cost avoidance and insignificant.

Other costs that would be attributed to the simulator, such as maintenance and security for the structure housing the simulator, and would thereby *decrease* the net cost avoidance were estimated and the total costs were similar to above in that they were orders of magnitude less than the net cost avoidance. Therefore, it was determined that we had captured the significant data for the cost avoidance calculation.

Figure 1 above is a synopsis of the cost avoidance methodology used in this study.

OBSERVATIONS AND FINDINGS

Cost Avoidance Discussion

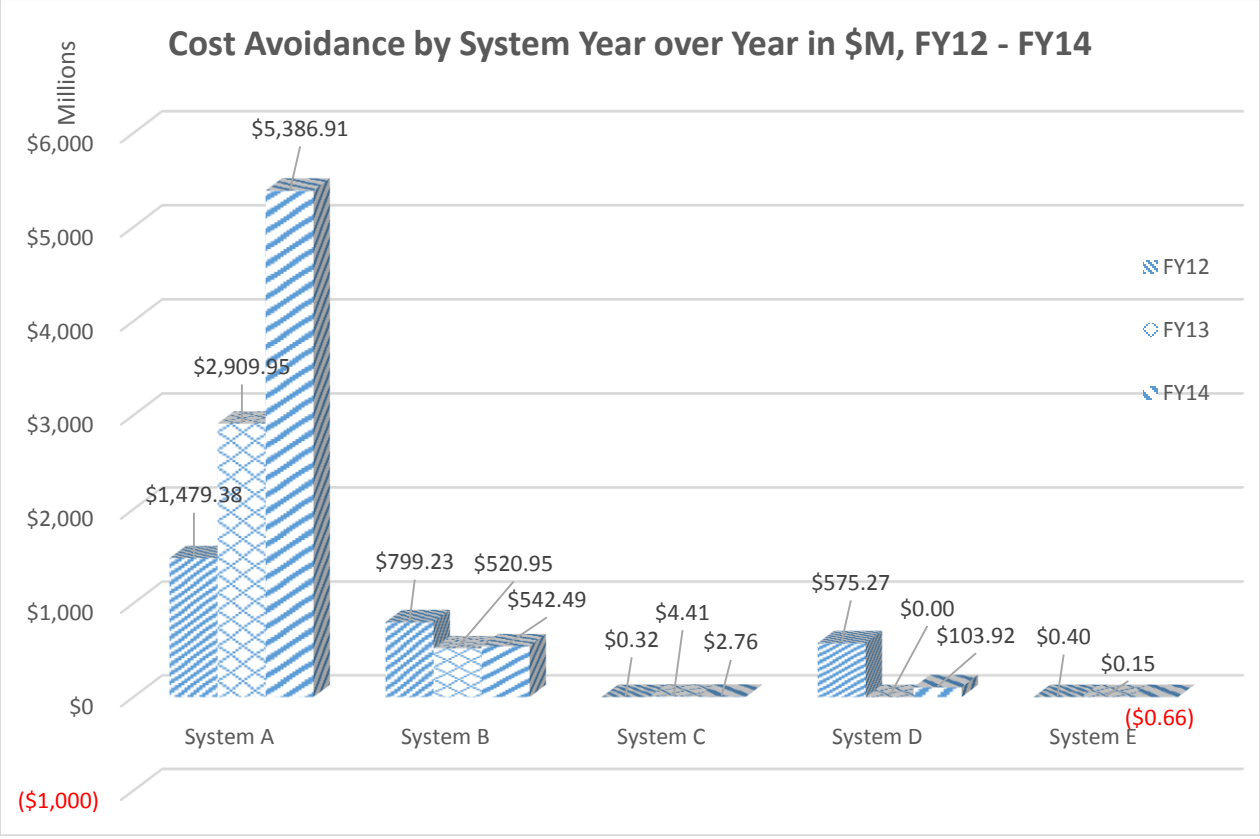

Figure 2. Net Cost Avoidance FY12-FY14 for All Systems in $M

Figure 2 above shows the net cost avoidance in $M for five training systems for FY12 thru FY14. These are the systems where the most complete data exists over the three fiscal years. At this time FY15 data is not included as it is incomplete, however, all systems have positive cost avoidance half-way through FY15. The Battle Staff trainers have the least amount of consistent data. However, for the years we have data, net cost avoidance ranges from $72M - $459M. The process for calculating net cost avoidance for Battle Staff trainers is the same process as described above, using the scenario data to determine the number of simulated rounds fired, simulated aircraft hours flown, simulated vehicle miles driven, simulated ordnance deployed, and the number of simulated Marines deployed in the scenario. The cost data for deploying a Marine Air Ground Task Force (MAGTF) is difficult to obtain as a MAGTF varies in size depending upon the mission. However, even without that data there is high net cost avoidance because of the sheer amount of munitions expended, aircraft sorties completed, and vehicle miles driven.

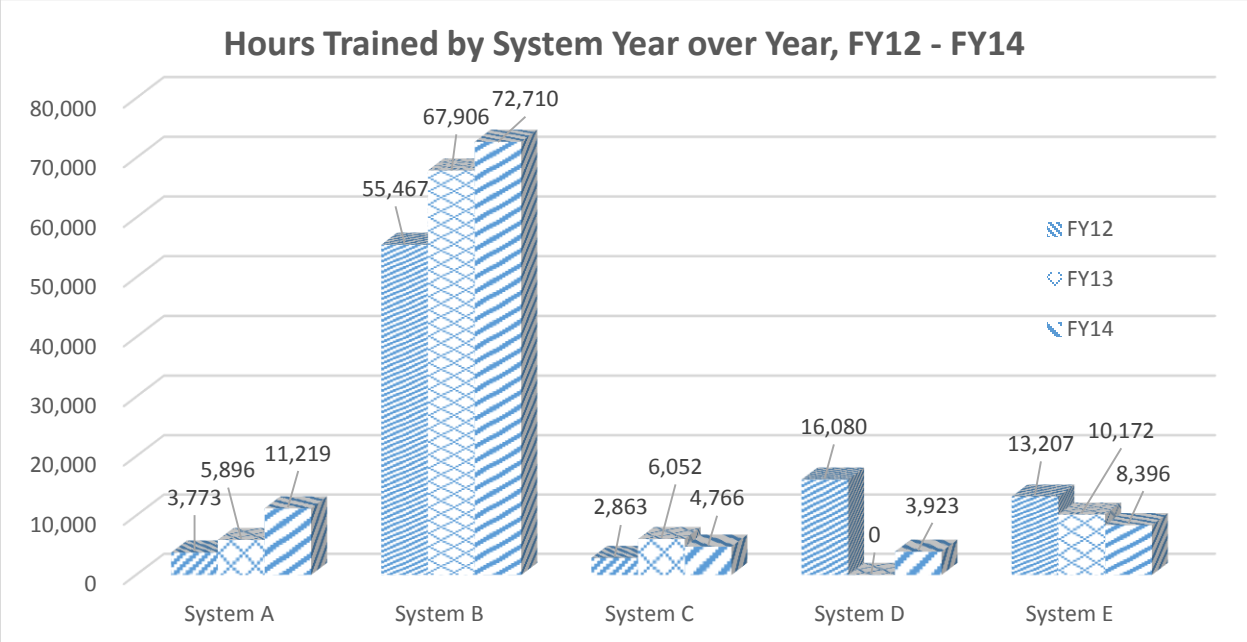

Figure 3. Hours Trained by System FY12-FY14

Figure 3 above shows the hours trained by system from FY12 – FY14. For system A, we see the net cost avoidance results following the trend of hours trained. However, while the hours trained increase by a factor of three from FY12 to FY14, the cost avoidance increases by a greater amount. This is attributed to a significant increase from FY12 to FY14 in the cost of one of the munitions used.

System B shows and increase in hours trained year over year, however, the cost avoidance is less in FY13 and FY 14 than FY12. Research into this situation showed that a rather expensive munitions decreased in cost by over 50% which resulted in a significant drop to net cost avoidance. Additionally, one site decreased their simulated use of that same expensive munition by 85%. The two of these events together accounted for the large majority of the decrease in cost avoidance.

System C had incomplete data in FY12. Usage and training data were reported for a maximum of six months at any given site. However, the simulator costs for the entire year were considered so the FY12 net cost avoidance is below the true value by approximately $1M. The simulator costs were considered for the entire year because they were expended and the training system was used for the entire year, hlwever, the data was not reported for the first 6 months.

For system D, FY13 data was lost during a software upgrade. Because the FY14 data was collected by the system and is very complete, it is believed that the FY12 data had some errors in collection. The number of hours trained using this system decreased by 75% from FY12 to FY14. This accounts for the majority of the decrease in cost avoidance.

System E has had minimal positive net cost avoidance, however, the qualitative benefits of the training system make it definitely worth having. The reason the cost avoidance went negative is that the ability to count part of the simulator training toward certification was removed from the T&R manual. This led to a significant decrease in usage (36%) and meant the costs avoided no longer cover the CLS cost for the simulator. There is a move to reinstate the ability to use part of the simulator training for certification which will move the net cost avoidance above zero again.

Table 2. Net Costs Avoided as a Percentage of Total System Cost

System	FY12	FY13	FY14
System A	81008%	168527%	568666%
System B	20344%	15602%	15260%
System C	10%	152%	95%
System D	25553%	N/A	4639%
System E	97%	16%	-54%

Table 2 above shows the *net* costs avoided as a percentage of total system cost calculated by dividing the net costs avoided by the total system cost. The costs included in this calculation are the costs explained above in the guiding principles. While the net cost avoidance numbers are clearly impressive, table 2 gives the picture of the net costs avoided as they relate to the costs expended. All systems have solid return on the investment with the exception of System E in FY14 and the reasoning behind that is described above. Note in FY13, System D data was lost and therefore labeled as not available. Since this table compares *net* cost avoidance (simulator costs subtracted from costs avoided) to total system cost, a return of 0% is interpreted as the costs avoided equaled the total system cost, a return of 100% means that the costs avoided were twice the total system cost. Over half of the cases have a net cost avoidance that is greater than 10 times the total system cost. System A provides a net cost avoidance that ranges from more than 800 times the total system cost up to over 5,600 times the total system cost. System B and D also give impressive numbers with returns typically over 100 times the total system cost.

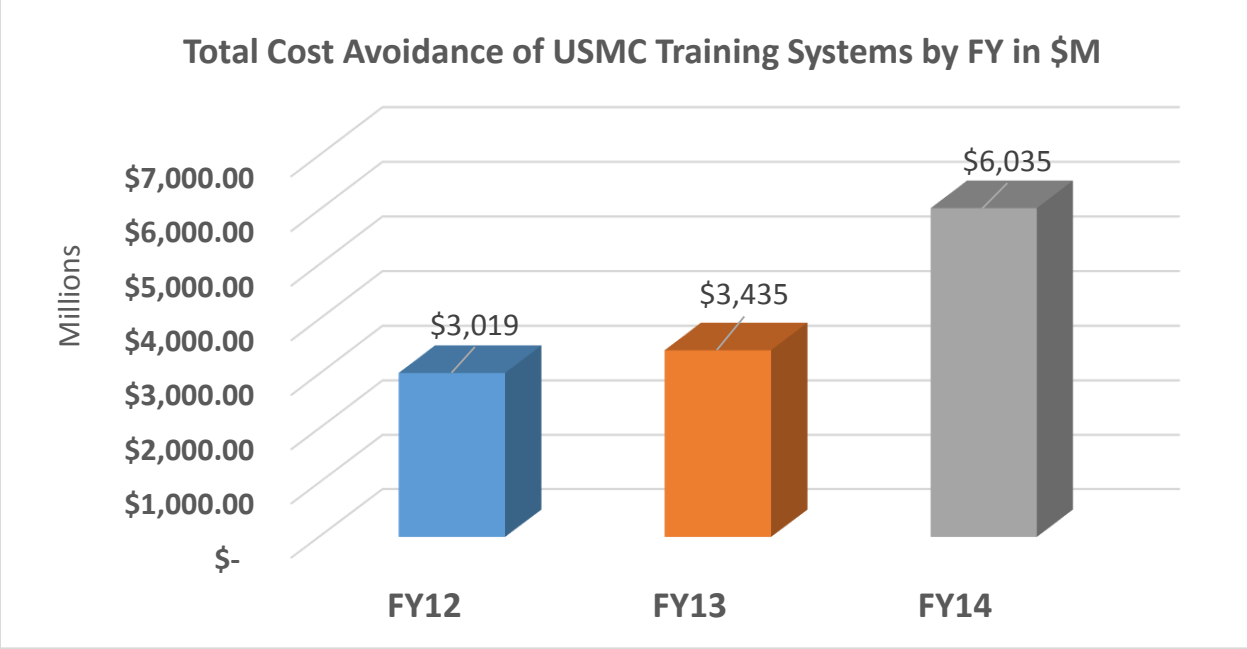

Figure 4. Total Net Cost Avoidance by FY

Figure 4, above, shows the total net cost avoidance by FY. These numbers consider data from other systems that didn't have consistent data to report. It is easy to see that the total net cost avoidance continues to increase. Of note is the fact that very little data is included from USMC Reserve sites. As that data becomes available, cost avoidance

will increase as some of the CLS costs for Reserve sites are included in the active duty sites and are difficult to extract. The total hours trained has increased by 10.5% from FY12 to FY14 which increases net cost avoidance, however, as discussed above there are other factors that influence net cost avoidance as well. Table 3 below shows the total net cost avoidance as a percentage of total system costs. Each year the return on the total portfolio is greater than 250 times the investment and is over 575 times the investment for FY14.

Table 3. Total Net Cost Avoidance as a % of Total System Cost

	FY12	FY13	FY14
% of Total System Cost	26029%	38523%	57814%

Other Information from Training Data

There are other potential uses for the usage and training data gathered to calculate cost avoidance. While space doesn't allow other charts and complete data to be depicted, examples of other information that can be gleaned are:

- Different training methods or scenarios at sites based upon different simulated munitions fired
- Change in training methods or scenarios depending upon simulated munitions fired
- Training throughput rates for each site and system
- System utilization rates at each site

System utilization rates by site (number of Marines trained and number of hours trained) are key management indicators which may show low usage of a simulator at one site and high usage of that same system as another site. This data can assist in optimizing simulator placement and, therefore, ensure the USMC gets the most value for their simulator dollars. There are some sites that are the only site that simulates firing certain munitions. This begs the question, "What training techniques or scenarios are they training that no one else does?" If there is a big spike in a month on the simulated use of a certain munition or aircraft this can lead to investigation of training practices and what precipitated the change. In one instance, investigation of a significant increase in the simulation of one munition found it was caused by the US Army beginning to use that system at that site for their training. Analyzing the number of Marines trained and the hours expended on training at each site (training throughput), can lead to best practices and the sharing of training techniques by the sites with higher training throughput. This means more efficient training across the Corps and, again, better utilization of scarce training dollars. All of these management indicators are consolidated and briefed to senior leaders using charts developed as a spin-off of the net cost avoidance calculations.

Challenges to Cost Avoidance Results

There are those who note the fact that the live ammunition, ordnance, and aircraft hours would never be used because there is not enough budget to support purchasing or expending those assets. For example, in FY14 there were greater than 8.6M 5.56mm simulated rounds fired in training systems. Were all of these expended in legitimate training and what if the simulator didn't exist? How would the training be accomplished? Certainly there are some T&R manuals that require simulator use and the simulated rounds fired can be directly tracked to T&R requirements. This analysis was performed for M16/M4 recertification requirements. Using the number of Marines that have to be recertified each year in M16/M4, the firing tables that must be completed for recertification, and the T&R manual that states what can be performed in a simulator, it was shown that approximately 35% of the 5.56mm rounds fired in the simulator could be directly tied to the recertification requirement alone. This doesn't consider familiarization training for basic training, initial certification training (which requires considerably more rounds to be fired), scenario training prior to deployment, etc. The AGTS proficiency study (Dunne, Cooley, Gordon, 2014) tied simulated ammunition expended directly to semi-annual certification training and calculated an annual net cost avoidance of $1M/crew just for semi-annual certification. This accounts for virtually all the cost avoidance for the AGTS system. Certainly, there are some simulated shots fired in system maintenance and testing and perhaps more shots fired in a simulated training scenario than would be fired for the same scenario on a live range. However, even if only 70% of the total net cost avoidance (suspected to be a low number) were directly tied to training requirements, the total would be > $2B per year for FY12 and > $4B for FY14. We anticipate only higher numbers as the data becomes more complete.

CONCLUSIONS

KEY POINTS

- A systematic, repeatable, process to calculate cost avoidance is achievable and valuable
- Analyzing key costs and benefits is critical to successfully calculating cost avoidance
- USMC simulation-based training currently avoids > $6B in live training costs
- Previous proficiency studies show simulator-based training increases trainee skill level in addition to avoiding costs
- Data collected for cost avoidance can be mined to inform management decisions to optimize training

This paper has shown a systematic, repeatable, process to calculate net cost avoidance for simulation-based training. While not considering every cost and benefit possible, the analysis has been completed which concludes that the significant factors have been considered in the net cost avoidance methodology. Using this methodology and data from the simulation-based training systems, total net cost avoidance is now >$6B per year. While there are various factors that affect net cost avoidance, as the data becomes more complete it is expected the total cost avoidance will increase. Additionally, each year the total hours trained in the simulation-based training systems increases and this should increase the total cost avoidance as well. Adding to the value of cost avoidance studies is the fact that the data can be mined to glean additional information. These management indicators, such as simulator usage and trainee throughput at each site, can be used to inform key management decisions which lead to better utilization of simulation-based training. However, it is not enough just to show that a simulation-based training system avoids live training costs, but in addition it must increase the proficiency of the trainee. A previous proficiency study using the AGTS showed that simulation-based training does increase trainee skill level. Coupling the increase in skill level with the live costs avoided is a significant part of showing that simulation-based training does indeed provide great value to the USMC.

FOLLOW-ON RELATED RESEARCH

As stated above, this methodology shows the value of simulation based training from a financial perspective. However, in the 2013 GAO report (GAO, 2013) they state "Without a means to assess the impact of using simulators on performance and to compare the costs associated with live training and the use of simulation-based training devices, decision makers in the Army and Marine Corps lack information to make fully informed decisions in the future regarding the optimal mix of training and related investment decisions." In other words, cost avoidance is good, but if the simulation-based training has little to no impact on performance then the overall value is minimal. To answer this question, PM TRASYS launched a Proof of Concept (POC) study of measuring the proficiency changes and cost avoidance due to use of the M1A1 AGTS simulation-based training system (Dunne, Cooley, Gordon, 2014). This study showed that it is possible, with well-defined performance metrics tied to doctrinal field and T&R manuals, to measure proficiency and calculate cost avoidance tied to tasks from the T&R manual. The cost avoidance methodology used there is the same as described in this paper. The study is currently on-going to use the framework developed in the POC for AGTS and calculate proficiency for the same systems where cost avoidance is calculated.

In August of 2014, the USMC held a Large-Scale Exercise (LSE-14) where virtual battlefields were integrated into live battlefields and simulation-based training systems were used for part of the exercise. The question arose, "Can the cost avoidance of using the virtual battlespace be calculated?" Using the same methodology listed above and limited data on simulated ammunition fired, simulated ordnance deployed, simulated aircraft hours flown, and simulated vehicle miles driven, a cost avoidance for the virtual part of LSE-14 was calculated as $5.7M. This calculation did not include a proportion of the CLS costs for each simulation system as it was considered those costs would be expended for each system even if the systems were not used for LSE-14. However, there were "constructive" Marines in some simulations in the virtual battlespace. Due to the lack of verifiable data, these simulated Marines were not considered in the cost avoidance calculation. These costs avoided could have increased the overall cost avoidance a significant amount. Efforts are in place to collect more data for upcoming exercises.

ACKNOWLEDGEMENTS

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of PM TRASYS. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation hereon. The

authors wish to acknowledge the assistance and cooperation provided by the logisticians and contract support staff for all the PM TRASYS simulation training systems who's names are too numerous to mention. Additionally, we would like to thank the PM TRASYS commanders throughout the study who provided support and guidance.

REFERENCES

Dunne, R., Cooley, T., and Gordon, S. (2014) "*Proficiency Evaluation and Cost-Avoidance Proof of Concept M1A1 Study Results"*, I/ITSEC 2014, Paper 14055.

Oswalt, I., Cooley, T., Waite, W., Waite, E., Gordon, S., Severinghaus, R., & Lightner, G. (2011). "*Calculating return on investment for US Department of Defense modeling and simulation",* Acquisition Review Journal, vol 18, No. 2, Issue 58, April 2011

Murphy, K., Farr, J., Loviscky, G. (2008), "Study to Quantify the Benefits and Costs of Simulated versus Live-Fire Training at USMC Ranges", Final Report Outline for the Office of Military and Security Programs, Contract M67854-05-D-5153, DO-0014, Oct 2008.

Dunn, W., Cobb, C., and Dickenson R., (1999) *Army Model and Simulation Office (AMSO) Benefits Initiative (Bi)*.

Mahon, R., (1999) *Modeling & Simulation Return on Investment (ROI) "Real Savings" Vs. Indirect Savings and Cost Avoidance*.

Gordon, S., (2000) *Determining the Value of Simulation*, in *SCSC 2000*. Vancouver, Canada.

Oswalt, I. (2005) "Navy M&S Value Analysis: Structure, Results & Ongoing Efforts", Report for the Navy Modeling and Simulation Office.

Gauvin, P., (2006) "Modeling and Simulation Cost Benefit Analysis Lists," Research Report prepared by AEgis Technologies.

Government Accountability Office. (2013). Army and Marine Corps Training Better Performance and Cost Data Needed to More Fully Assess Simulation-Based Efforts, GAO-13-698.